College as lecturer on the application of statistics to social and political science; George P. McKee has been appointed instructor in physics.

PROFESSOR CHARLES R. RICHARDS, director of the manual training department of the Pratt Institute, Brooklyn, has been appointed to the chair of manual training in the Teachers' College, Columbia University.

AT the University of Cambridge, Mr. F. C. Kempson and Mr. R. H. Biffen, of Gonville and Caius College, have been appointed demonstrators of anatomy and botany respectively.

DISCUSSION AND CORRESPONDENCE.

WEATHER HARMONICS.

THE study of weather periodicity has, from the beginning of meteorology, attracted, more or less, the time and attention of students. Yet, so baffling and uncertain are the results so far produced that many have been led into the scepticism voiced by a recent writer, who remarks, 'There is, apparently, no periodicity in the recurrence of weather.' It seems to me, however, that this attitude is the same as that of a student who visited the track of a tornado, expecting to find the trees and other débris lying in perfect circles, but on finding the fallen trees lying over each other pointing in different directions, and other débris in tangled confusion, came back and announced his conviction that no whirl existed in the tornado funnel. In other words, my study of the subject for many years convinces me that it is the complexity of the data, not the absence of the phenomenon, which has induced this scepticism in regard to weather periodicity.

I am led to the conclusion, which is extremely important if true, that one of the complexities which has helped to obscure weather periodicity is the existence of what may, perhaps, be called weather harmonics, on account of the resemblance to harmonics in sound—that is, the existence of other periods related to the primary as 2, 3, 4, etc. In what follows I shall briefly outline the evidence on which this conclusion is based.

For the first examples I take the best known and only generally accepted cycles, the annual and daily periods. The first harmonic periods I wish to point out are multiples of a year, namely, two, three, four and eight years in length, all of which are continuously acting, but now and then one becomes predominant, so that it may be selected for illustration.

Thus, over the interior of the United States there were for many years very marked oscillations of pressure, temperature and humidity covering a period of about two years. These were discussed in the *American Meteorological Journal*, Vol. I., pp. 130 and 528. The data appeared at first to indicate a period about a month longer than two years, but later investigation indicates that it is more exactly two years. Three and four-year multiples have not been marked in the United States, but an eight-year period has been well marked. Thus the Chief of the Weather Bureau gives, in his latest report (1897, p. 23), the years of widespread drought in the United States during the last forty years as follows, 1860, 1863, 1870-71, 1881, 1887 and 1894-95. An eight-year series, running as follows, 1863, 1871, 1879, 1887 and 1895, takes in four out of six droughts. This seems to have been acting with the eleven-year or sun-spot period, the maxima of which occurred about 1860, 1870, 1883 and 1894, and are apparently connected with droughts in the United States. In the British Isles during the last 50 years three, four and eight-year periods appear to have been equally active, hence no simple rhythm can be selected for illustration. But I desire to call attention to one striking fact. It is well known that harmonic sound waves, after a certain number of oscillations, occur with their like phases together, and form beats, and it might be expected that harmonic weather periods, if they exist, would likewise form beats. Since 24 is a common multiple of 2, 3, 4 and 8, extremes of weather would be expected to be separated by such an interval. Now, it is a curious fact that the curves published by A. B. MacDowall, showing the number of frost days at Greenwich, show very marked extremes at this interval. For example, the greatest number of frost days were in 1855 and 1879, 24 years apart, while the least number were in 1872, 1884 and 1896, separated by intervals of 12 and 24 years. (See *Meteorological Zeitschrift*, 1897, p. 384.)

I have reason to believe there are also periods

of a-half, a-third, etc., years, but these appear to be less marked than the multiples of years.

There are also weather periods which are even multiples of days. The most marked of these are 3, 4, 5 and 8 days. On account of limited space I can only illustrate one period, and because of accessible data I have selected the 4-day period. Taking the observations of temperature at 8 a. m. and 8 p. m., made at the Blue Hill Meteorological Observatory during 1895, and obtaining the departures from the normals, the residuals were classified into 4-day periods. The means of each six periods were then obtained and are given in the following table:

1895.	MEAN DEPARTURES IN DEGREES FAHRENHEIT.				
Jan. 20–Feb. 12	−3 −3	−1 +2	+3 +3	+2 −1	
Feb. 13–Mar. 8	+2 +2	0 −1	−2 −1	+1 +2	
Mar. 9–April 1	+2 +2	+1 −1	−1 −1	−1 +1	
Apr. 2–April 25	+2 +1	−2 −2	−1 +1	+2 +3	
Apr. 26–May 29	+3 +1	−2 −3	−3 −1	+3 +4	
May 30–June 12	+2 +3	+2 +1	−1 −2	−2 −1	
June 13–July 6	0 +1	0 0	0 −1	0 +1	
July 7–July 30	0 +1	0 +1	+1 +1	0 0	
July 31–Aug. 23	0 0	−1 0	0 −1	0 +1	
Aug. 24–Sept. 16	+3 +1	0 −2	−2 −1	+1 +2	
Sept. 17–Oct. 10	+2 +3	+2 0	−2 −2	−1 0	
Oct. 11–Nov. 3	+2 +3	+2 0	−1 −2	−2 0	
Nov. 4–Nov. 27	+2 +1	−1 −2	−1 +1	+2 +2	
Nov. 28–Dec. 21	+1 +3	+2 +1	−1 −2	−2 −1	

This table shows that throughout the year plus departures are found on the first day of the period, with but one exception; while on the third day, out of twenty-eight recorded means, twenty-one were minus departures. This period, has continued equally well marked and mainly with the same phase during the last three years. The range of temperature in the period is about four degrees, while the mean daily range of temperature from hourly records at Blue Hill is about 10° F. Under certain conditions there is a semi-diurnal oscillation in the temperature (Annals of Harvard College Observatory, Vol. 20, p. 123).

One further illustration will be sufficient, perhaps, to show the universality of the harmonic law. For this I have selected the 22-year or double-sunspot period. Mr. R. C. Mossmann gives a table in the Transactions of the Royal Society of Edinburgh, Vol. XXXIX., p. 187, showing for Edinburgh the departures of temperature from normal, from 1764 to 1896, smoothed by continuous five-year groups. These means show little or no trace of an eleven-year period, but in Mr. Mossmann's plotted curve of the annual means show six distinct waves of a length of about 22 years. Thus the minima of the waves occurred as follows:

Observed Minima	1772	1784	1815	1838	1860	1879
22-year cycle	1771	1793	1815	1837	1859	1881

With the exception of 1784 these dates differ but little from that of an exact 22-year cycle, and approximate very closely the dates of minimum in the same cycle in New England, in Iceland and in Paris (*Nature*, Vol. 51, p. 436). The annual averages in Mr. Mossmann's table were classified into six periods of 22 years, beginning with 1766, and averages were obtained from each year of the cycle. These, in tenths of a degree Fahr., are as follows:

Year of cycle	1	2	3	4	5	6	7	8	9	10	11
Means	+2	+3	+1	−1	−3	−6	−6	−5	−3	−1	+1
Mean error ±	5	7	7	6	5	4	5	4	5	3	3
Year of cycle	12	13	14	15	16	17	18	19	20	21	22
Means	+2	+3	+7	+5	+6	+6	+2	+1	+0	+1	+1
Mean error ±	3	3	4	2	1	2	2	4	3	5	3

These means show a well marked period, and at the epochs of maximum and minimum the means are considerably larger than their mean errors. At the time of maximum, between the 14th and 17th year of the period, the means are nearly three times as large as their mean errors, an unusually favorable showing in the case of a meteorological cycle. Dr. Schreiber's curves of the eleven-year period in rainfall, published in the Abhandlung des Konigl. sachs. meteorologischen Institutes, Plate IV., show that the eleven-year period at Dresden and Freiberg is made up of two primary waves of nearly equal magnitude and two secondary waves midway between the primary.

The harmonics in the case of periods of other lengths were pointed out in the *American Journal of Science*, Vol. XLVIII., p. 231. The application of these weather cycles to forecasting is interfered with: (1) by the multiplicity of the cycles and their independent variations in amplitude according to some unknown law; (2) the oscillations of the cycles (including the annual and daily cycles) simultaneously in different phases in different parts of the world (see *American Meteorological Journal*, Vol. I., p. 528); (3) the sudden inversion of the phase

of the cycle from time to time at any one point on the earth's surface. Number (3) appears to be true for every cycle except the annual and diurnal cycles, and is the most difficult and confusing condition that confronts the believer in weather cyles. The formula

$$\Sigma \frac{\cos nx}{n^2 - 8^2}$$

is a mathematical expression of the sudden inversion of phase which may take place in harmonic curves, as is beautifully shown by Professor Michelson's harmonic analyzer. Whether this, however, has any relation to weather curves is uncertain.

I feel strongly that the difficulties will in time be solved, and that forecasting by means of weather cycles will supplant largely, if not entirely, all other forms of weather forecasting.

H. HELM CLAYTON.

BLUE HILL METEOROLOGICAL OBSERVATORY,
HYDE PARK, MASS., February 8, 1898.

SCIENTIFIC LITERATURE.

The Ruins and Excavations of Ancient Rome. A Companion Book for Students and Travelers. By RODOLFO LANCIANI. Boston and New York, Houghton, Mifflin & Co. 1897. Small 8vo. Pp. xxiv+619.

This book will be a godsend to the more intelligent class of English-speaking travelers, who are not obliged to limit themselves to a very short stay in Rome. Few, indeed, are the persons who have not felt somewhat bewildered when they have been called upon to map out their time for a winter in the Eternal City so as to use it to the best purpose.

The ordinary guidebook, no matter how good it may be, is not enough; Middleton's 'Ancient Rome,' which is in many ways almost indispensable, is written largely from an architect's point of view; the various German works are for the most part intended more for professional students of antiquity, and Professor Lanciani's other two books, 'Ancient Rome in the Light of Recent Discoveries' and 'Pagan and Christian Rome,' are of too popular a character to be very useful, if a person wishes to undertake a serious, albeit a not strictly professional, study of the ruins of the city. There was, therefore, need for just such a book, which should cover substantially the whole field and which should include the most recent results of Roman topographical investigation, as the one before us. Its usefulness will, however, by no means be confined to intelligent travelers, for, to quote from the preface, 'students wishing to attain to a higher degree of efficiency in this branch of Roman archæology (viz., topography) will find copious references to the standard publications on each subject or part of a subject.' Indeed, the skill with which Professor Lanciani has constantly kept in mind the needs of these two classes of readers, without thereby spoiling the unity of his book or making it unfit for either class, is worthy of high praise. The enormous mass of material which must be handled in any treatment of Roman topography has been arranged and presented with simplicity and skill; questions in dispute have been indicated without lengthy discussion, and thus the dryness so characteristic of works in which the statement of a very large number of facts is necessary has been in a great measure avoided.

In Book I. of his work, which contains 'general information,' Professor Lanciani has gathered together a large amount of material that is not easily accessible. The geological formations about the city, the climatic conditions, the quarries, the bricks and the Tiber are discussed. The walls in different periods, the bridges, the aqueducts, the *cloacæ*, the regions of Augustus and the maps of the time of Severus —what might, in fact, be termed the anatomy of the city—are also treated here. Some interesting statistics, too, in regard to population and the amount of the water supply have been included. Books II. and III. are concerned with the very heart of the city—the Palatine Hill and the Sacra Via from Coliseum to Capitol—and here is included also the discussion of the Forum Romanum and of the adjoining *fora* of imperial times. In book IV. the rest of the city is described according to the Augustan Regions and there is a brief concluding chapter on the 'general aspect of the city.' This is followed by an appendix containing lists of the Emperors, Popes and artists and useful information touching chronology, weights and